HYDROGEOLOGIC EVALUATION OF DELISTING
PART OF THE TULARE LAKEBED AREA

Draft Report

prepared for
Tulare Lake Basin WSD and
Tulare Lake Drainage District
Corcoran, California

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April 2013
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EXECUTIVE SUMMARY

1. The historical Tulare Lakebed has been proposed for MUN (Municipal and Domestic Supply Beneficial Use) delisting. The purpose of this report is to present a technical basis for recommending a de-designation of MUN for the first encountered groundwater in the Tulare Lakebed. Data on geologic subsurface conditions, location of existing water supply wells, and the electrical conductivity of the shallow groundwater are presented to provide a basins for recommending a de-designation.

2. The subsurface geologic conditions, the absence of public supply wells, and high electrical conductivities of the shallow groundwater in the central part of the Tulare Lakebed confirms that the central area does not require further evaluation for de-designation of MUN. Clay layers are predominant in the central part of the lakebed, and interbedded sand layers are generally not present.

3. Four subareas along the fringe of the Tulare Lakebed were selected for further evaluation (Figure 1). The subareas are adjacent to cities and/or communities (Corcoran, Alpaugh, Kettleman City, and Stratford) which rely entirely on groundwater for their supply. Subsurface geologic condi-
tions, records on water supply wells, the directions of groundwater flow, and shallow groundwater quality were the major factors considered in the evaluation of each of the subareas.

4. Of particular importance are clay and other fine-grained deposits within the uppermost several hundred feet of the subsurface. The U.S. Geological Survey has identified three relatively shallow clay tongues around the margins of the Tulare Lakebed. High salinity groundwater is present beneath most of the lakebed area above the shallowest of these (the A and B-Clays). In contrast, lower salinity groundwater is often present below the deepest of these (the C-Clay). Shallow clay and other fine-grained layers are effective confining beds that limit the downward flow of shallow high groundwater to greater depths.

5. There are only a few water supply wells along the west and south margins of the lakebed, primarily due to an abundance of clay and high salinity groundwater.

6. There are records for a number of water supply wells along the north fringe of the lakebed, including a number of private domestic wells southeast of Stratford. Such wells may not be sealed off opposite all of the higher salinity shallow groundwater (generally above a depth of about 200
feet). There are also records for a number of other domestic wells in the north part of the East Subarea, between Corcoran and Alpaugh. In addition, there are public supply wells at Stratford, Kettleman City, Alpaugh, and northeast of Corcoran. To address MUN concerns, the recommended delisting boundary has been placed to exclude the vicinities of these wells.

7. The originally proposed delisting boundary was largely validated along most of the west and south parts of the lakebed. However, the boundary was moved to the south in parts of the North Subarea, primarily due to the presence of numerous domestic wells (Figure 28). The largest change in the delisting boundary from that originally proposed was in the East subarea. The boundary was moved to the west in part of this subarea due to:

a) The proposal to use one or more wells in the Angiola W.D. west field for public supply in Alpaugh.

b) The presence of a number of domestic wells in this area.

c) Lower salinity shallow groundwater apparently associated with recharge from Tule River streamflow.

8. The recommended delisting boundary is shown in Figure 29.
HYDROGEOLOGIC EVALUATION OF DELISTING
PART OF THE TULARE LAKEBED AREA

INTRODUCTION

The historical Tulare Lakebed has been proposed for MUN (Municipal and Domestic Supply beneficial Use) delisting (Figure 1). The purpose of this report is to present a technical basis for recommending a de-designation of MUN for the first encountered groundwater in the Tulare Lakebed. Data on subsurface geologic conditions, location of water supply wells, and the electrical conductivity of the shallow groundwater are presented to provide a basis for recommending a de-designation.

The lakebed has several distinct characteristics in terms of subsurface geologic and groundwater conditions, compared to most other parts of the San Joaquin Valley. Clay is predominant in most of the subsurface, with the exception of some areas near the margins of the lakebed. This is due to the closed nature of the surface water drainage, and the distance of the lakebed from the heads of the major alluvial fans to the east and south. In general, clay layers are more than 2,000 feet thick beneath large parts of the lakebed, a much greater thickness than found anywhere else in the Central Valley. The major streams that historically flowed into the lakebed are the Kings, Kaweah, Tule, and Kern Rivers and Poso and Deer Creeks. Drainages from the Coast
Range to the west have contributed only relatively small amounts of water to the lakebed.

Over the millennia, salt naturally accumulated in the lakebed deposits and the shallow groundwater, due to the closed nature of the basin and the past evaporation of water in the lake and of shallow groundwater beneath the lakebed. Because of these two features, virtually all of the lakebed is not underlain by a usable shallow groundwater supply. There are no known large capacity water supply wells in the central part of the study area. Rather, both surface water, including the Kings River and imported state supplies, and groundwater from adjoining areas, particularly from the north and east, have been brought into the lakebed area for irrigation.

There are four urban areas on the upslope areas of the fringe of the lakebed that are evaluated herein. These are Corcoran, Stratford, Kettleman City, and Alpaugh. Groundwater is used for public supply in these areas, although arsenic treatment has been necessary for the groundwater pumped in the City of Corcoran. Due to natural factors, there are a number of groundwater quality problems in and near the lakebed area. Included are high concentrations of total dissolved solids (TDS), arsenic, iron, manganese, fluoride, uranium, color, hydrogen sulfide, and methane gas. Because of these problems, the Tulare Lakebed vicinity has been
among the most difficult or impossible areas in the San Joaquin Valley to develop groundwater of suitable quality for public supply or irrigation purposes.

Because of these conditions, the focus of this evaluation is on the fringe areas. Less attention is given to the central part of the lakebed, which is more distant from public supply and drinking water wells, and is an area of extensive clay deposits and very high salinity shallow groundwater.

Subareas for Evaluation

In order to facilitate data mapping and display of hydrogeologic information for this evaluation, the fringe of the Tulare Lakebed delisting area was divided into four study subareas (Figure 1). The boundaries of each subarea were generally delineated to extend several miles in both directions from the originally proposed delisting boundary (Figure 1).

The North Subarea is located between Kent Avenue and Orange Avenue. This subarea generally covers the north part of the lakebed and adjoining areas, including Stratford. The Westlake Farms North Evaporation basins are located just north of this subarea. The south branch of the Kings River and several branches of the Kaweah River pass through this subarea.

The West Subarea generally extends to the west to near Ket-
tleman City, and extends from Orange Avenue on the north to the Garces Highway on the south. The Westlake Farms South Evaporation Basins are in this subarea. No large streams pass thorough this subarea.

The South Subarea extends from 22nd Avenue on the west to Road 32 on the east, and is primarily south of Virginia Avenue. The Tulare Lake Drainage District (TLDD) Hacienda and South Evaporation Basins are in this subarea. No urban areas are located in the subarea. The Kern River overflow channel passes through the south part of this subarea.

The East Subarea extends from Orange Avenue on the north to one mile south of Virginia Avenue on the south. This subarea includes the City of Corcoran and Alpaugh, and the Tule River passes through the central part of the subarea. The east boundary of this subarea is west of part of the original delisting boundary. This is because of a recent proposal to supply water from one or more Angiola W. D. wells that are located between Roads 32 and 40 for public supply in Alpaugh. This project is to mitigate high arsenic concentrations in the Alpaugh public supply. Thus the recommended delisting boundary in this area would be moved to the west from that originally proposed, to west of these wells. Because of this, the eastern boundary of the East Subarea was selected to be at Road 40.

The revised delisting boundaries as the result of this evaluation are termed "recommended delisting boundaries" in this report.
SUBSURFACE GEOLOGIC CONDITIONS

Regional Conditions

Croft (1972) of the U.S. Geological Survey prepared several subsurface geologic cross sections extending through the Tulare Lakebed. Croft's sections were based entirely on electric logs or geologic logs from coreholes. He identified six "clayey or silty clay tongues", designated by letter symbols A to F, beneath the fringes of part of the lakebed. The most widespread of these are the A, C, and E Clays. The E-Clay is also known as the Corcoran Clay, and is the most laterally extensive confining bed in the San Joaquin Valley. Of particular interest in this delisting evaluation are the A-Clay, the B-Clay, and the C-Clay. The average depths of these clays in the Tulare Lakebed area, where they can be identified, are about 60, 130, and 230 feet, respectively. High salinity groundwater is common above the first two of these clays and sometimes below the B-Clay. Lower salinity groundwater is usually present beneath the C-Clay and in some areas also below the B-Clay. The shallowest public supply wells in or near the lakebed are for the City of Corcoran, and some of these tap sands above the C-Clay. However, most of the production from these wells is from below the C-Clay. Kettleman City wells tap strata above the Corcoran Clay. Other public supply wells (in Corcoran and elsewhere) tap sand below the Corcoran Clay. In the lakebed proper, clay is predominant to several thousand feet in
depth, and these tongues are usually not distinguishable from the other clay that is present (Figure 2). Figure 2 extends from the northwest to the southeast through the Tulare Lakebed, from northwest of Stratford extending to the Kings/Kern County line just southwest of Alpaugh.

Kenneth D. Schmidt and Associates (KDSA) have prepared several subsurface cross sections for the west part of the North Subarea, the north part of the West Subarea, and for the east part of the East Subarea. As part of this evaluation, some of the previous KDSA subsurface geologic sections were supplemented and a number of new cross sections were developed. These sections include data from electric logs and drillers logs, and thus are based on data from many more wells than were Croft's cross sections. Because the most important confining beds relative to the high salinity shallow groundwater are above a depth of about 250 feet, most of the sections were prepared to only show strata above this depth. However, some deeper cross sections that were prepared prior to this evaluation were used near urban areas, where deeper groundwater is tapped.

North Subarea

Figure 3 shows the locations of four subsurface geologic cross sections in the North Subarea. Because the originally proposed
FIGURE 2-GENERALIZED SUBSURFACE GEOLOGIC CROSS SECTION FOR TULARE LAKEBED AREA
FIGURE 3 - LOCATION OF SUBSURFACE GEOLOGIC CROSS SECTIONS IN NORTH SUBAREA
delisting boundary in this subarea is primarily oriented in the east-west direction, most of these sections are oriented from north to south. Cross Section A-A' extends from the north-north-east near Stratford, to the southwest to near Nevada Avenue and 23rd Avenue (Figure 4). This section is generally parallel to the originally proposed delisting boundary, and is generally near the northwest edge of the lakebed in this area. This section indicates the predominance of clay in this area, as no large streams apparently passed through this area during most of the past when the upper 250 feet of deposits were laid down. Clay is so predominant, that none of the "tongues" identified by Croft can be identified.

Cross Section B-B' extends from near Kansas Avenue and 18th Avenue on the north, to the south to near Manteca Avenue and 19th Avenue (Figure 5). The historic Kings River is indicted to have passed through part of this area at some times, and sand layers are more predominant along the part of the section north of Madison Avenue. Clay becomes predominant toward the south (at Wells 21A, 27D, and 33A). The A-Clay (several layers) can be identified at Wells 10R and 21J. Sands below the A-Clay are particularly discontinuous along this section. The other two clays (B-Clay and C-clay) can't be readily distinguished because of the preponderance of clay.
FIGURE 5 - SUBSURFACE GEOLOGIC CROSS SECTION B - B'
Cross section C-C’ extends from north of Kansas Avenue near 16th Avenue to the south, to near Manteca Avenue and 16th Avenue (Figure 6). This section generally shows similar subsurface geologic conditions as does Section B-B’ (Figure 5). Some sands are present to the north, but these thin and pinch out to the south. Clay is predominant south of Laurel Avenue along this section. Near the north end of the section, the A-Clay, the B-Clay, and the C-Clay can be identified. The A-Clay appears to be in the interval between about 30 to 100 feet in depth. The B-Clay appears to be in the interval between about 135 to 170 feet in depth. The top of the C-Clay was indicated to be near sea level, or at a depth of about 210 to 215 feet. South of Lincoln Avenue along this section, the three clay tongues are indistinguishable, due to the predominance of clay. Some shallow sands within the upper 50 feet or so are fairly continuous along the north part of this section. At least two sands between the A-Clay and B-Clay are apparently continuous in this area. At least one sand layer just above the C-Clay is apparently continuous along the part of the section north of Lincoln Avenue.

Cross Section D-D’ extends from between Kansas and Lansing Avenues near 14th Avenue on the north, to the south to between Manteca and Nevada Avenues and east of 14th Avenue (Figure 7). This section is far enough east that former branches of the
FIGURE 6 - SUBSURFACE GEOLOGIC CROSS SECTION C - C'
Kaweah River likely passed through the area. The A-Clay, B-Clay, and C-Clay appear to be distinguishable along the section. Near the north end of the section, the A-Clay is present between above 60 and 95 feet in depth. This clay deepens to the south, and near the south end of the section is about 75 to 120 feet deep. The B-Clay is distinguishable along the part of the section north of Manteca Avenue. The top of this clay averages about 130 feet deep, and the bottom averages about 170 feet deep along the section. The upper part of the C-Clay is distinguishable along all of the section. The top of this clay is an average of about 210 feet deep along the section. A fairly continuous sand layer is present above the A-Clay along the part of the section north of Manteca Avenue. Another sand layer between the A-Clay and B-Clay is also fairly continuous along this part of the section. One or more sand layers between the B-Clay and C-Clay appear to be continuous along most of this section.

The subsurface geologic cross sections indicate that the originally proposed delisting boundary does not need to be moved on the basis of subsurface geologic conditions. This is because of the abundance of clay in the subsurface at and near the boundary.

West Subarea

Figure 8 shows locations of subsurface geologic cross sec-
in the West Subarea. Cross Section E-E' and part of Section F-F'
were previously developed by KDSA (2002) for a City of Lemoore
WWTF evaluation and extend deep enough to include the Corcoran
Clay.

Cross Section E-E' extends from near Orange Avenue and east
of the 26th Avenue to the south, to near Redding Avenue and 26th
Avenue (Figure 9). The south end of this section is about one
and a half miles northeast of Kettleman City. The A-Clay is dis-
tinguishable along the north part of this section, in the inter-
val between 60 and 90 feet in depth. Below this clay and to the
south, clay is predominant along the section. Several laterally
discontinuous sand layers are present between the A-Clay and a
depth of about 250 feet.

Cross Section F-F' extends from Kettleman City to the north-
east, near Quebec Avenue and 4th Avenue (Figure 10). This sec-
tion extends downward to the Corcoran Clay, because Kettleman
City public supply wells tap strata below 250 feet in depth and
above the Corcoran Clay. All of the Kettleman City wells are
outside of the originally proposed delisting boundary. Laterally
extensive clays are predominant, and the A-Clay and C-Clay are
distinguishable along the section. The top of the Corcoran Clay
is about 600 to 700 feet deep along the section. Sand strata
thin and pinch out to the east along the section.
Cross Section G-G' extends through the south part of the West Subarea, from near Utica Avenue and I-5 on the west to the east, to near Tucson Avenue and east of the 22nd Avenue (Figure 11). A sand layer was found within the upper 60 feet at Well 10P. This sand layer pinches out to the east and clay is predominant beneath the east part of the section.

The subsurface geologic cross sections indicate that the originally proposed delisting boundary is supported by subsurface geologic conditions. This is because of the abundance of clay in the subsurface at and near the boundary.

South Subarea

Figure 12 shows the locations of subsurface geologic cross sections in the South Subarea and the TLDD Hacienda and South Evaporation Basins. Subsurface Section H-H' extends from the north between 18th and 19th Avenues, about one mile south of Virginia Avenue, to the south to about one mile south of the Kings County-Kern County line, and east of the alignment of 16th Avenue (Figure 13). Clay is predominant above a depth of about 250 feet along the part of this section south of 16th Avenue. Several sand layers are present at Well 11P, but are not present at Wells 10N and 30N. The A and B-Clays can be delineated at Well 7B1. The deepest of the three clays (C-Clay) can be identified along part of the section.
FIGURE 11 - SUBSURFACE GEOLOGIC CROSS SECTION G - G'
The top of this clay is indicated to be at an elevation of about 25 feet below sea level, or at a depth of about 230 feet, at Well 11P.

Cross section I-I' extends from about a mile east of Interstate 5 and the extension of Cecil Avenue to the east to near Corcoran Road and Avenue 4 (Figure 14). The A-Clay can apparently be distinguished along the west edge of the section, between about 30 and 65 feet in depth, and near the east edge. The top of the C-Clay is indicated to be at an elevation of about 10 feet below sea level, or a depth of about 220 feet at Well 2P1. The ancestral Kern River is indicated to have passed through at least part of this section, and several sand layers are present at Well 1N4. Clay is predominant below a depth of about 150 feet along most of the cross section, except near the east edge. A fairly laterally continuous sand is indicated to be present beneath the central part of the section at a depth of about 40 to 60 feet. Another fairly continuous sand is indicated along the eastern part of the section below the C-Clay at a depth of about 240 feet.

The subsurface geologic cross sections indicate that the originally proposed delisting boundary does not need to be moved on the basis of subsurface geologic conditions. This is because of the abundance of clay in the subsurface at and near the boundary. In addition, high salinity shallow groundwater and a lack of
FIGURE 14 - SUBSURFACE GEOLOGIC CROSS SECTION I - I'
public supply and drinking water wells indicate that this boundary could be moved farther to the southwest and south in part of the area. The recommended delisting boundary has been moved as shown in Figure 12, and is discussed further in a subsequent section of this report. A one mile buffer was provided around the Tulare Lake Drainage District (TLDD) South Evaporation Basins.

East Subarea

Figure 15 shows the locations of subsurface geologic cross sections in the East Subarea. Two of the cross sections (J-J’ and K-K’) were previously developed for the Angiola W.D. Two additional cross sections (L-L’ and M-M’) were developed for this evaluation, both extending approximately in the east-west direction.

Cross Section J-J’ extends from the north near Avenues 112 and Road 36 to the south to Alpaugh (Figure 16). The A-Clay was delineated in Alpaugh at a depth of about 110 feet, and along the central part of the section, between Avenues 76 and 108. The C-Clay was delineated along most of the section south of Avenue 112. The top of this clay averaged about 200 to 250 feet deep. The top of the Corcoran Clay is shown, and productive sands are present between the C-Clay and Corcoran Clay along the part of the section north of Avenue 76. Numerous sand layers are present along much of this section, most of which is east of the lakebed proper.
These sands were likely deposited by the ancestral Tule River. This section passes through the west well field of the Angiola Water District, where highly productive sands are present both above and below the Corcoran Clay.

Cross Section K-K' extends from the west near Avenue 56 and Road 11 to the east to near Avenue 88 and Road 44 (Figure 17). The east part of this section passes through the west well field of the Angiola W.D. This section extends to a depth of about 2,000 feet and shows the Corcoran Clay. The clay was distinguishable at several wells, and is about 150 feet deeper than the A-Clay. This section indicates that many sands become thinner or pinch out toward the lakebed proper. Clay becomes predominant below the Corcoran Clay along the part of the section west of Road 32.

Cross Section L-L' extends from the west near Seattle Avenue and 5th Avenue to the east to north of Avenue 112 near Road 36 (Figure 18). Clay is predominant along the part of the section west of Road 24. The A-Clay is distinguishable along the section below a depth of about 30 feet and above a depth of about 60 feet. The B-Clay may be present at an average depth of about 120 feet along parts of the section. The C-Clay is also distinguishable, and generally the top of this clay is near sea level, or at an average depth of about 200 feet. Sand layers are generally discontinuous along this section.
FIGURE 17-SUBSURFACE GEOLOGIC CROSS SECTION K-K'
FIGURE 18 - SUBSURFACE GEOLOGIC CROSS SECTION L - L'
Cross Section M-M' extends from the west near Quail Avenue and 8th Avenue to the east to near Avenue 144 and 4th Avenue (Figure 19). Clay is predominant along the west part of this section. The A-Clay is distinguishable along the east part of the section between about 25 and 70 feet in depth. The C-Clay is distinguishable along the west and east parts of the section, below a depth of about 220 to 230 feet. There are a number of sand layers present in the area east of 5th Avenue.

The subsurface geologic cross sections indicate that the originally proposed delisting boundary does not need to be moved to the west on the basis of subsurface geologic conditions, except south of the Tule River. This is because of the abundance of clay in the subsurface in the rest of the area.

**KNOWN WATER SUPPLY WELLS**

Information on water supply well locations and types was taken primarily from U.S. Geological Survey "Well Data" reports and DWR well completion reports, and City or Department of Health Services records. Construction data for active public supply wells are provided in Appendix A.

**North Subarea**

Figure 20 shows locations of supply wells in part of the North Subarea. There are records for five public supply wells in
FIGURE 20 - LOCATION OF KNOWN WATER SUPPLY WELLS IN NORTH SUBAREA
Stratford. These are outside of the originally proposed delisting boundary, and are discussed in a later section of the report. There are a number of private domestic wells located in part of the originally proposed delisting area. Because many of these wells may not be sealed off opposite the high salinity (electrical conductivity) shallow groundwater, it is advisable to not include them in the area to be delisted. There are several other private domestic or small water system wells close to the originally proposed delisting boundary (Figure 20), and the boundary was moved slightly to exclude them from the delisting area. In the rest of this subarea proposed for delisting, there are only a few supply wells used for irrigation.

**West Subarea**

Figure 21 shows locations of known supply wells in the West Subarea. Several of these wells were abandoned due to poor water quality. Records are available for four public supply wells in Kettleman City. Three of these wells are still active. Records are available for two old private domestic wells near Salem Avenue and 27th Avenue, but they may no longer be active. These public supply and domestic wells are indented to tap strata above the Corcoran Clay. Records are also available for five industrial wells located near Highway 41 between Quebec Avenue and Redding Avenue, and four other industrial wells west of 27th
Avenue between Racine Avenue and Salem Avenue. Most of these industrial wells no longer exist. The northerly industrial wells range in depth from about 1,350 to 1,700 feet and primarily tap strata below the Corcoran Clay. The southerly industrial wells tap strata above the Corcoran Clay. The recommended delisting boundary has been moved to the east to exclude these wells. Records are available for four irrigation wells north of Quebec Avenue and four other irrigation wells north of Salem Avenue, between 26th and 27th Avenues. These wells are indicated to primarily tap strata below the Corcoran Clay. Records are also available for five stock wells south of Tucson Avenue. These are indicated to be shallow, likely tapping strata above the Corcoran Clay.

South Subarea

Figure 22 shows locations of known water supply wells in the South Subarea. There are records for only three private domestic wells and all of these are east of Corcoran Road and outside of the proposed delisting area, and are abandoned. There are records for four stock wells in the west part of the subarea. Two of these are within the recommended delisting area and are abandoned. There are records for a number of irrigation wells in the southeast part of the subarea, and all of them are outside of the recommended delisted area. The recommended delisting boundary
was previously discussed in the subsurface geologic conditions section of this report for this subarea.

**East Subarea**

Figure 23 shows the locations of known water supply wells in the originally proposed area for delisting in the East Subarea. Only wells west of Road 40 are shown in the east part of the subarea. City of Corcoran supply wells are all in the area northeast of Highway 43 and well out of the area proposed for delisting. The primary Alpaugh public supply well is also located outside of the area proposed for delisting. There were several drinking water wells near Road 21 and south of Avenue 136, but these are no longer present. There are records for a number of private domestic wells in the east part of Section 21 and the west part of Section 22, T21S/R22E. These are west of Corcoran and inside the area originally proposed for delisting. There are records for a number of other private domestic wells in the area south of Avenue 144, north of Avenue 120, and east of 5th Avenue. There are no known records of other private domestic wells in the remaining part of the subarea recommended for delisting. There are a number of irrigation wells west of Corcoran and south of Corcoran and north of Avenue 120 in the subarea. South of Avenue 104, almost all of the irrigation wells in the subarea are near
Road 40 or farther east. The recommended delisting boundary was moved to the west from that originally proposed to exclude the areas where private domestic wells are or were present.

WATER LEVELS

Shallow groundwater levels are discussed in this section. Because of the importance of urban areas to this evaluation, the direction of shallow groundwater flow in and near these areas is also discussed.

Depth to Water

The shallowest groundwater in most of the lakebed area is less than 20 feet deep. Detailed maps showing the water-level elevations and direction of shallow groundwater flow are generally unavailable except in specific areas, such as at and near the Westlake Farms Evaporation Basins. Figure 24 is a topographic map of the lakebed. Available data indicate that the direction of shallow groundwater flow in most of the lakebed area generally follows the topography, flowing from the exterior part of the subareas shown in Figure 1 toward the center of the lakebed. Thus near the fringes of the lakebed, the direction of groundwater flow is toward the interior of the lakebed.

Information on vertical differences in water levels for the
shallow groundwater is available from U.S. Geologic Survey multiple completion monitor well sites and at or near some of the evaporation basins. Beard, Fujii, and Shanks (1994) provided water-level data for four cluster monitor wells sites in the Tulare Lakebed area. At Site T19S/R20E-29E, north of Stratford, there was little difference in water levels for two monitor wells that were 50 feet deep or shallower. However, the water level at a depth of 80 feet was about 12 feet lower than in the shallower strata. At a depth of 190 feet, the water level was about 65 feet lower than a depth of 80 feet.

At Site T20S/R21E-4F, located east of Stratford, the water
level at a depth of 51 feet was about five feet lower than at a depth of 15 feet. At a depth of 98 feet, the water level was about 14 feet lower than at a depth of 51 feet. At a depth of 195 feet, the water level was about 20 feet lower than at a depth of 98 feet.

At Site 24S/R26E-5B, located southwest of Alpaugh, there was little difference in water level between 15 and 95 feet in depth. However, between 95 and 180 feet in depth, there was a difference of about 51 feet. At Site T25S/R21E-1N, located near the southwest edge of the lakebed in Kern County, there was very little difference in water levels above a depth of 194 feet. At this particular location, the water level at a depth of 194 feet was actually several feet shallower than at a depth of 95 feet, indicating an upward direction of groundwater flow. This is probably due to the lack of groundwater pumping in the vicinity.

The most important conclusion from the water-level data for the shallow groundwater is that the significant vertical water-level differences in the absence of pumping are an indication of the extremely low hydraulic conductivities of clay layers, in particular, the A and B-clays. Considering the low vertical conductivities of the clay layers, this means that there is very little if any downward flow of groundwater.


Directions of Groundwater
Flow Near Urban Areas

Stratford

Data for the primary public supply well (Appendix A) in Stratford indicates that it is perforated from 660 to 1,170 feet in depth and taps strata below the Corcoran Clay. The deposits above the Corcoran Clay are sealed off in this well. The direction of shallow groundwater flow is indicated to be to the south, based primarily on monitoring at the Westlake Farms North Evaporation Basins and on the topography. Shallow groundwater would not influence the quality of groundwater pumped from the Stratford supply wells because of the intervening clay above the top of the perforations. In addition, all of these public supply wells are located outside of the recommended delisting boundary.

Kettleman City

There are three active public supply wells in Kettleman City. Two of these well are about 400 feet deep and the other is 630 feet deep (Appendix A). All of these wells are indicated to tap strata above the Corcoran Clay, which is indicated to be below a depth of about 800 feet near Kettleman City. The direction of shallow groundwater flow is indicated to be to the east, based primarily on the topography and the direction of groundwater
flow at the Westlake Farms South Evaporation Basins. All of these public supply wells are located outside of the recommended delisting boundary.

Alpaugh

The primarily supply well in Alpaugh is perforated from 1,025 to 1,210 feet in depth and taps strata below the Corcoran Clay. This well is sealed off opposite all strata above a depth of 900 feet (Appendix A). The direction of shallow groundwater flow near Alpaugh is indicated to be to the west, based on topography.

The two Angiola W.D. wells (G-3 and G-5) which could be used for Alpaugh are perforated from about 200 to 500 feet in depth and tap strata above the Corcoran Clay. The direction of shallow groundwater flow in that area (between Avenues 104 and 112 and Roads 32 and 40) is indicated to be to the west, based on topography. Shallow groundwater within the recommended delisting area would not influence the quality of water pumped from the Angiola W.D. well or wells, because of the intervening clay layers above the top of the perforations. In addition, the originally proposed boundary was moved to the west to exclude these potential public supply wells.
City of Corcoran

Active City of Corcoran public supply wells are located east of 5th Avenue and north of Orange Avenue. All of these wells are located more than two miles outside of the recommended delisting boundary. Two of these wells (No. 8 and No. 9) tap strata above the C-Clay and have perforations extending up to 120 and 116 feet in depth, respectively. These two wells are located between Orange and Niles Avenues and 4½ and 5th Avenues. The remaining active City wells (Appendix A) have perforations below a depth of 194 feet and are located farther to the north or northeast of City Wells No. 8 and 9 (farther from the recommended delisting area). Four active City of Corcoran wells tap strata below the Corcoran Clay.

The direction of shallow groundwater flow above a depth of about 50 feet in Corcoran is indicated to be to the west, based on topography. High salinity shallow groundwater in the area to be delisted would not influence the quality of water pumped from City of Corcoran wells, due to the presence of the A-Clay, the annular seals in these wells, and the distance of the wells from the recommended delisting boundary.

GROUNDWATER QUALITY

As used in this report, the "shallowest groundwater" is that
closest to the water table, primarily above a depth of about 50 feet. This can also be termed the "first encountered groundwater". "Deeper shallow groundwater" is generally between about 50 feet and 200 feet in depth. The chemical quality of groundwater below the C-Clay is primarily discussed only in the vicinity of the four urban areas.

Information on the chemical quality of groundwater above a depth of about 200 feet was obtained from several sources:

2. Monitoring reports for shallow groundwater at and near the Westlake Farms and TLDD evaporation basins.
5. Recent monitoring results for dairies and other sites in the study area.

North Subarea

Figure 25 shows electrical conductivities (micromhos/cm @ 25°C) of groundwater in the North Subarea.
FIGURE 25 - ELECTRICAL CONDUCTIVITY OF SHALLOW GROUNDWATER IN NORTH SUBAREA
Shallowest Groundwater

Data available in or near this subarea are from the Westlake Farms North Evaporation Basins monitoring, from the referenced U.S. Geological Survey reports, backhoe excavations, and for other monitoring programs, such as at dairies. The shallowest groundwater samples are primarily for wells or excavations less than about 30 feet deep. The highest electrical conductivities exceeding 10,000 micromhos have been found in the west part of the subarea, primarily near or northwest and west of Highway 41. In most of the rest of the subarea north of the originally proposed delisting boundary, electrical conductivities of the shallowest groundwater have exceeded 4,500 micromhos and have generally been highest to the west and south. The electrical conductivities at only three sites (all in Section 2, T21S/R21E) in this subarea were less than 4,500 micromhos.

In part of the area south of Nevada Avenue and east of 20th Avenue, Tulare Lakebed land owners have measured electrical conductivities of the shallow groundwater in numerous backhoe excavations. The results are provided for such holes north of Newton Avenue. All of these electric conductivities exceeded 10,000 micromhos.

In summary, the high electrical conductivities of the shallowest groundwater support the originally proposed delisting
boundary in this subarea, except for a small area south of Nevada Avenue and east of 12th Avenue. The recommended delisting boundary was moved from that originally proposed to exclude this area. This boundary was also moved in certain areas to exclude domestic wells, as previously discussed.

Deeper Groundwater

There are data for a deep monitor well near the TLDD North Evaporation Basins. Well NEB-A tapped groundwater at a depth of about 95 feet. The electrical conductivities of water from this well ranged from about 3,200 to 3,600 micromhos when monitoring first began in 1975-76. The electrical conductivities of water from this well ranged from 3,000 to 3,400 micromhos in 2010-2012. Additional data area available for three cluster monitor wells at Site T20S/R21E-4F. Electrical conductivities were much lower in samples from below a depth of 93 feet, and were as follows in 1990-91.

<table>
<thead>
<tr>
<th>Depth Interval (feet)</th>
<th>Elec. Cond. (micromhos/cm @ 25°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-20</td>
<td>5,490</td>
</tr>
<tr>
<td>93-103</td>
<td>928</td>
</tr>
<tr>
<td>190-200</td>
<td>1,530</td>
</tr>
</tbody>
</table>

Similar information is available for four cluster monitor wells at Site T19S/R20E-29E, as follows:
<table>
<thead>
<tr>
<th>Depth Interval (feet)</th>
<th>Elec. Cond. (micromhos/cm @ 25°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-20</td>
<td>21,500</td>
</tr>
<tr>
<td>40-55</td>
<td>41,700</td>
</tr>
<tr>
<td>75-85</td>
<td>38,200</td>
</tr>
<tr>
<td>185-195</td>
<td>15,200</td>
</tr>
</tbody>
</table>

At this site, high salinity groundwater was still present to a depth of almost 200 feet. This well is about a mile and a half north of the North Subarea and about half a mile northeast of the Westlake Farms North Evaporation Basins.

**West Subarea**

Figure 26 shows electrical conductivities of the shallowest and deeper groundwater in the West Subarea.

**Shallowest Groundwater**

Electrical conductivities are available for 14 wells, all of which are about 20 feet deep, in this subarea. Some of these wells are near the Westlake Farms South Evaporation Basins. Electrical conductivities of water from all of these wells exceeded 10,000 micromhos. Values ranged from 12,600 to 59,200 micromhos and were generally lowest in the central part of the subarea, east of Kettleman City. For the part of the area east of 22nd Avenue, backhoe excavations were dug by landowners and electrical conductivities measured (Appendix B). Electrical
conductivities for all of this shallow groundwater exceeded 10,000 micromhos. These values were similar to those for shallow groundwater in U.S. Geological Survey monitor wells to the west and within about three miles of the excavations.

Deeper Groundwater

Information on the chemical quality of groundwater between 30 feet and 250 feet in depth is not known to be available in this subarea.

South Subarea

Figure 27 shows electrical conductivities of shallow groundwater in the South Subarea.

Shallowest Groundwater

Electrical conductivities of the shallowest groundwater have been measured at many sites in the part of this subarea east of 12th Avenue. Included are data from monitor wells for the Tulare Lake D.D. Hacienda and South Evaporation Basins. There are two U.S. Geological Survey cluster monitor well sites (T24S/R23E-5B and T25S/R21E-1N) where additional data are available. In the part of the subarea east of 10th Avenue and north of the extension of Avenue 36, Tulare Lakebed landowners collected samples of
shallow groundwater in a number of backhoe excavations for electrical conductivity measurements (Appendix B).

Most of the monitor wells tapping the shallow groundwater range from about 10 to 50 feet deep. Electrical conductivities in water from these wells and the backhoe excavations exceeded 10,000 micromhos in much of the subarea. One well west of the TLDD South Evaporation Basins had water with an electrical conductivity of only 1,750 micromhos. This Well T25S/R21E-1N1) is perforated from 10 to 20 feet in depth and is adjacent to a local ditch. The electrical conductivity is indicated to not be representative of other areas. Groundwater at that site between 52 and 62 feet in depth had an electrical conductivity of 12,000 micromhos, which is considered representative of the shallowest groundwater in the vicinity. Electrical conductivities in water from four excavations north of the Hacienda evaporation basins ranged from 1,600 to 3,400 micromhos. These lower electrical conductivities are likely the result of tile drains collecting irrigation water from recently irrigated fields. Only one other shallow well (HEB-13-1A) near the Hacienda Evaporation Basins had an electrical conductivity of less than 10,000 micromhos (9,300 micromhos) in 2009-10. Thus the representative electrical conductivity of shallow groundwater in this subarea substantially exceeds 10,000 micromhos, with some values exceeding 40,000
micromhos. Data indicate that the south boundary of the originally proposed delisting area in Kern County could be moved farther south, because high salinity shallow groundwater extends at least several miles south of the Kern County line in this area.

Deeper Groundwater

There are five monitor wells at or near the TLDD Hacienda Evaporation Basins that range in depth from about 80 to 100 feet. Electrical conductivities in water from those wells ranged from about 4,600 to 25,000 micromhos. Overall, the salinity of the deeper groundwater was less than that of the shallowest groundwater in this subarea, but was still relatively high. There are five monitor wells at or near the TLDD South Evaporation Basins that are about 100 feet deep. The electrical conductivities of water from these wells ranged from 2,900 to 47,000 micromhos. There was only one well (SEB6-2) with an electrical conductivity of less than 4,500 micromhos. At the other three sites, electrical conductivities exceeded 40,000 micromhos. There is a monitor well that is perforated from 90 to 100 feet in depth northeast of the Trico Gas Field. The electrical conductivity of water from Well T24S/R23E-5B5 was 8,900 micromhos. There are two U.S. Geological Survey monitor wells in the subarea that tap strata in the interval between 175 and 200 feet in depth. The electrical
conductivity of water from Well T25S/R21E-1N4 was 4,540 micromhos and the electrical conductivity of water from Well T24S/R23E-5B6 was 2,380 micromhos. This relatively lower salinity deeper groundwater is separated from the overlying high salinity groundwater by significant clay layers.

**East Subarea**

Figure 28 shows electrical conductivities of the shallowest groundwater in the East Subarea. There are a substantial amount of data from U.S. Geological Survey monitor wells and landowner backhoe excavations.

**Shallowest Groundwater**

Electrical conductivities for the shallowest groundwater are primarily from samples above a depth of about 20 feet. A distinct geographical distribution of electrical conductivities is apparent in the East Subarea. Electrical conductivities of the shallowest groundwater exceeded 10,000 micromhos in the area south of Avenue 96 and southwest of a line extending from near Quebec Avenue and 9th Avenue to the southeast, to near Avenue 96 and Road 40. Electrical conductivities were less than 4,500 micromhos in an area primarily south of the Tule River, and east of 8½ Avenue. The south boundary of this area was near Road 40,
FIGURE 28 - ELECTRICAL CONDUCTIVITY OF SHALLOW GROUNDWATER IN EAST SUBAREA
and between Avenues 102 and 112. The north end of this area was in the south part of the City of Corcoran. In the area between Paris Avenue and Racine Avenue, the transition from lower salinity (less than 4,500 micromhos) to higher salinity (more than 10,000 micromhos) shallowest groundwater occurred in a relatively short distance (less than a mile).

**Deeper Groundwater**

There is little information on the salinity of groundwater between a depth of about 30 feet and 250 feet in this subarea. However, sampling of water for a test well in Alpaugh adjacent to the recommended subarea boundary indicated an electrical conductivity of 1,330 micromhos at a depth near 250 feet. Thus groundwater below the C-Clay in this area is of much lower electrical conductivity than that of the shallowest groundwater (indicated to range from about 30,000 to 57,000 micromhos) in the vicinity.

**Composite Tulare Lakebed Area**

Figure 29 shows electrical conductivities of the shallowest groundwater for the composite lakebed area, including the subareas on the fringe previously discussed and in the central part of the lakebed. This illustration documents the high salinities of the shallowest groundwater beneath most of the lakebed.
CONCLUSIONS ON RECOMMENDED DELISTING BOUNDARIES

Figure 30 shows the recommended delisting boundaries in the lakebed area as the result of this evaluation. The recommended boundaries and the changes from the originally proposed boundaries are discussed by subarea.

North Subarea

The primary revision in the North Subarea is for an area southeast of Stratford, where records are available indicating a large number of private domestic wells (Figure 20). Therefore, the delisting boundary was moved several miles to the south, primarily between 17th Avenue and 20½ Avenue. A second part of this subarea where the boundary was moved south was south of Nevada Avenue between 10th Avenue and 12th Avenue. The subsurface geologic conditions, supply well locations, and shallowest groundwater quality data support the originally proposed boundary in the rest of this subarea.

West Subarea

The originally proposed delisting boundary near Kettleman City was moved about half a mile to the east to exclude the industrial wells north of and near Kettleman City. Most of these wells were abandoned due to water quality problems. The rest
FIGURE 30
RECOMMENDED DELISTING BOUNDARY
of the originally proposed boundary is supported by subsurface geologic conditions, supply well data, and shallowest groundwater quality data.

South Subarea

The original westerly delisting boundary in T24S was moved to the southwest, because of the presence of shallow clay layers, the lack of domestic wells, and the relatively high electrical conductivity of the shallowest groundwater. Clay strata are indicated to be predominant and the electrical conductivities of the shallow groundwater in this part of the lakebed exceed 4,500 micromhos. The recommended delisting boundary was also moved from that originally proposed near the TLDD South Evaporation Basins. South of the South Evaporation Basins, clay is predominant in the subsurface and information in Kern County indicates electrical conductivities exceeding 10,000 micromhos in the shallowest groundwater. There are also no records of domestic wells in the area south of these basins and within a distance of one mile. Thus this boundary was moved south over a width of three miles in this part of the subarea.

East Subarea

The originally proposed delisting boundary was moved to the
west in part of this subarea south of Corcoran and north of Alpaugh, primarily because of the presence of lower electrical conductivities in the shallowest groundwater south of the Tule River, and also because of supply well locations.

Recent backhoe excavations by landowners in a large part of this area (Figure 28) indicated electrical conductivities in the shallow groundwater exceeded 4,500 micromhos. The direction of shallow groundwater flow in this area is to the west, based on the topography. The A-clay is present at a depth of approximately 40 feet below the ground surface and provides a barrier between the shallow groundwater and the upper most usable groundwater (Figures 17, 18, and 19). The supply well information (Figure 23) indicates there are or were several drinking water wells in the area south of the Tule River and north of Racine Avenue (Avenue 120) between Highway 43 and 6th Avenue. For this reason, the recommended boundary has been shifted to the southwest in this area. In addition, the boundary was moved westerly from one mile north of Avenue 88 to Avenue 120 because of the proposed use of one or more Angiola W.D. wells for public supply in Alpaugh. These changes were the largest changes from the originally proposed boundary for the lakebed area. Also, considering the location of the City of Corcoran public supply wells northeast of Corcoran, well beyond the study area boundary, de-
listing of the shallow groundwater within the recommended MUN
delisting boundary in the East Subarea is reasonable. This is
based on the subsurface geologic conditions, shallow groundwater
quality, and the location of public supply and drinking water
wells.

**Summary**

The subsurface geologic and groundwater quality evaluations
along with the information on supply wells required some recom-
mended changes to the originally proposed delisting boundary.
The evaluation demonstrates that the shallow groundwater does
not serve as a source of water supply for municipal and domestic
supplies within or immediately adjacent to the recommended de-
listing area, and it is not anticipated that it will in the fu-
ture. Therefore, this recommended delisting will not result in
degradation of drinking water or public water supplies.

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APPENDIX A

CONSTRUCTION DATA AND CHEMICAL ANALYSES
FOR PUBLIC SUPPLY WELLS
APPENDIX B

EXCAVATION WATER SAMPLING
METHODOLOGY AND RESULTS